DECONTAMINATION AND BENEFICIAL REUSE OF CONTAMINATED RIVER SEDIMENTS USING CEMENT-LOCK^{TM} TECHNOLOGY

FINAL REPORT
(May-August 1997)

Prepared by

Anil Goyal
Michael C. Mensinger
Amir Rehmat

INSTITUTE OF GAS TECHNOLOGY
1700 South Mount Prospect Road
Des Plaines, Illinois 60018-1804

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GAS RESEARCH INSTITUTE
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GRI Project Manager
S. Peter Barone
Senior Technology Manager

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16. Abstract (Limit: 200 words)

The Cement-Lock Technology, developed by the Institute of Gas Technology (IGT), offers a one-step solution for treating various types of contaminated materials. In the process, organic contaminants are completely destroyed, inorganic contaminants are immobilized, and the resultant solid product is converted to cement for sale in the marketplace. Implementing this technology would significantly increase the use of natural gas.

In the current program, dredged Detroit River sediments were mixed with inexpensive modifiers (83% dried sediments, 17% modifiers) and melted at about 2260°F. The melt was then rapidly quenched with water to retain the desired amorphous phase with latent cementitious properties. The amorphous material produced was then converted to blended cement per ASTM procedures.

The untreated sediments contained oil and grease, PAHs, PCBs, and heavy metals. In the final product, the organic contaminants were below the analytical detection limit, indicating that these contaminants were completely destroyed in the process. The results of the EPA TCLP procedure conducted on the blended cement showed that the leachability of the priority heavy metals was significantly below the regulatory limits. This demonstrated that the metals present in the untreated sediments were immobilized in the final product. The 3, 7, and 28-day compressive strengths of the blended cement were 2245, 2910, and 4600 psi, respectively; these strengths exceed ASTM C 595 and ASTM C 1157 requirements.

17. Document Analysis

a. Descriptors

Contaminated Sediment, River Sediment, Decontamination, Organic Destruction, Destruction and Removal Efficiency, Metal Immobilization, EPA Leachability, TCLP, Compressive Strength

b. Identifiers/Open-Ended Terms

Cement-Lock Process, Remediation, Natural Gas-Fired Melter, Ecomelt, Blended Cement, Portland Cement, Beneficial Reuse

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EXECUTIVE SUMMARY

This report presents the results of an experimental program conducted by the Institute of Gas Technology (IGT) under a contract with the Gas Research Institute (GRI) for "Decontamination and Beneficial Reuse of Contaminated River Sediments Using Cement-Lock™ Technology." The overall objectives of the program were to apply IGT's Cement-Lock Technology to decontaminate dredged river sediments to produce a salable end product from the sediments and to determine some of the important physical and chemical properties of the end product. Construction Technology Laboratories, Inc. (the research arm of the Portland Cement Association) was a subcontractor to IGT on this program.

The Detroit River has been identified as an environmental area of concern due to a number of impaired beneficial uses including contaminated sediments and dredged benthic communities. The Trenton Channel and Rouge Turning Basin contain some of the most highly contaminated sediments in the Detroit River. A representative sample of sediments from this basin was used in this program for testing.

The Cement-Lock Technology, developed by IGT, offers a one-step solution for treating various types of contaminated materials in which the organic contaminants are completely destroyed, inorganic contaminants are immobilized, and the resultant solid product can be put to a beneficial use (Business Week, 1997; Baker, 1997). The technology is flexible enough to accommodate the complex and varying nature and levels of contaminants and their widespread spatial distribution within the river beds. The technology is capable of simultaneously handling the fixation of heavy metals and the destruction of polynuclear aromatic hydrocarbons (PAHs) and organochlorines such as dioxins, furans, polychlorinated biphenyls (PCBs), chlorinated pesticides, and herbicides. Natural gas is the most suitable source of energy for this recycle and reuse technology. About 5 BCF of natural gas is required to process one million tons of sediments.

The dredged river sediments sample was analyzed for its major/minor oxides content. Then a raw-mix formulation was designed for producing Ecomelt™ (a cementitious material) from the sediments. The mix formulation, containing 83 percent sediments and 17 percent inexpensive modifiers, was melted in a muffle furnace at a temperature of approximately 2260°F (1238°C). The melt was then withdrawn from the furnace and quickly quenched in cold water to prevent crystallization and retain the amorphous phase. The melt product (Ecomelt) was dried in air. Then blended cement was produced using the Ecomelt per ASTM C 595 specification. Two-inch mortar cubes were prepared using the blended cement (per ASTM C 109 procedure) for compressive strength determination.

The following results were obtained from the bench-scale experimental study conducted in this program:

- The organic contaminants in the blended cement (end product of the Cement-Lock process), such as oil and grease, PAHs, and PCBs, were below the detection limit of the analytical procedures used. This indicates that these species, which are present in the untreated sediments, are completely destroyed in the process.
- The results of the EPA TCLP procedure conducted on the blended cement product showed that the leachability of the priority metals from the blended cement was significantly below the regulatory limit for each of the metals. This demonstrates that the metals present in the untreated sediments are immobilized in the final product.
- The blended cement produced from the contaminated sediments and modifiers generated 3, 7, and 28-day compressive strengths greater than those required for general purpose cement. It is significant to note that activators (performance enhancing additives) were not added to the blended cement product.

Previous studies conducted at IGT with dredged estuarine sediments at bench-scale and pilot-scale levels had yielded similar results in terms of organic destruction, metals immobilization, and cement quality. The bench-scale results obtained in this study with river sediments are expected to be confirmed during pilot-scale operation also. Therefore, the technology is ready for application at a larger scale of operation.

The Cement-Lock process economics are also very favorable because of the dual revenue streams associated with the process: processing (tipping) fees received for the contaminated sediments and revenues received from the sale of the cement product. The next step is to conduct a pilot-scale study and to identify a commercialization team consisting of an A&E company, an equipment manufacturer, a cement company, a gas company, and private investors.

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INTRODUCTION

Background

Persistent high concentrations of contaminants in the bottom sediments of rivers and harbors have raised considerable concern about potential risks to aquatic organisms, wildlife, and humans. Exposure to contaminated sediments may impact aquatic life through the development of cancerous tumors, loss of habitat, and toxicity to fish and benthic organisms. Exposure can also impact wildlife and human health via the bioaccumulation of toxic substances through the food chain. As a result, advisories against fish consumption are in place in many locations. These advisories, along with closed commercial fisheries and restrictions on navigational dredging, have significant adverse economic impacts on affected areas.

The Detroit River has been identified as an environmental area of concern due to a number of impaired beneficial uses including contaminated sediments and dredged benthic communities. The Trenton Channel and Rouge Turning Basin contain some of the most highly contaminated sediments in the Detroit River. A representative sample of sediments from this basin was used in this program for testing.

The Cement-Lock™ Technology, developed by the Institute of Gas Technology (IGT), offers a one-step solution for treating contaminated materials in which the organic contaminants are completely destroyed, inorganic contaminants are immobilized, and the resultant solid product from the treatment is put to a beneficial use (Business Week, 1997; Baker, 1997). The technology is flexible enough to accommodate the complex and varying nature and levels of contaminants and their widespread spatial distribution within the river beds. The Cement-Lock Technology is capable of simultaneously handling the fixation of heavy metals, and the destruction of polynuclear aromatic hydrocarbons (PAHs) and organochlorines, such as dioxins, furans, polychlorinated biphenyls (PCBs), chlorinated pesticides, and herbicides. Natural gas is the most suitable source of energy for this recycle and reuse technology. About 5 BCF of natural gas is required to process one million tons of sediments. As a beneficial use, Cement-Lock Technology produces cement from contaminated sediments for sale in the merchants market. Cement was selected as a beneficial-use product due to the reasons stated below.

The decline in the infrastructure of the U.S. cement industry is well documented. The United States has gone from being a cement exporting nation in the 60's to a cement importing nation in the 90's due to increasing demand for cement by the construction industry (Figure 1). Demand is rising by an average of about one percent per year – or about 800 thousand metric tons. U.S. production, however, has not kept pace with demand. In 1996, the U.S. cement shortfall was about 15.8 million tons. At this rate of cement demand increase, the cement shortfall in the United States will be well over 150 million tons in the next decade.

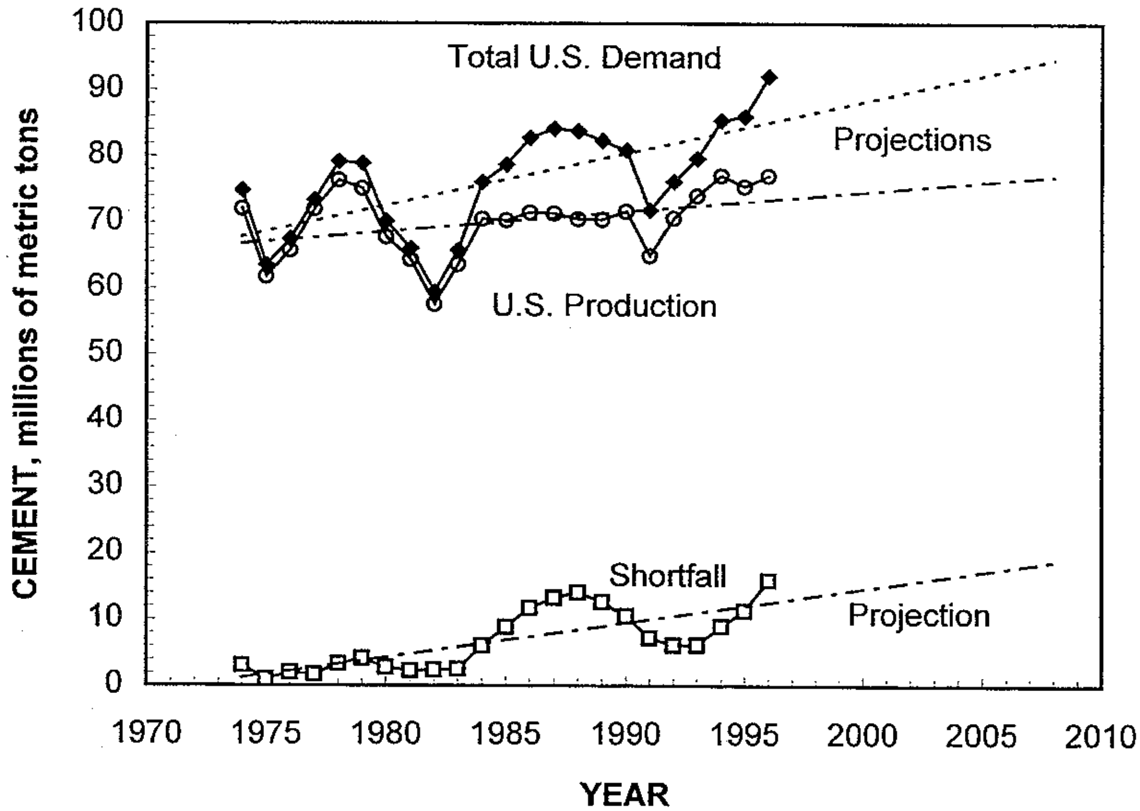


Figure 1. DEMAND AND PRODUCTION OF CEMENT IN THE UNITED STATES

New cement manufacturing capacity is being added slowly. About 70% of U.S. cement manufacturing facilities are over 25 years old. Exorbitant construction costs, environmental regulations, and increased cost of raw materials and energy – compounded by stagnant cement prices due to imports – are major reasons for the stifled growth in the cement industry. Conditions are not expected to improve until new and innovative ideas are implemented that provide attractive returns for manufacturers.

The Cement-Lock Technology offers an outstanding solution to revitalize the cement industry infrastructure at a fraction of the capital cost, while utilizing raw materials and wastes that actually generate revenues from their use. Thus, a supplemental cement supply can be produced and sold at prices comparable to or less than those of the conventional portland cement.

Program Objectives

The overall objectives of the program were to apply IGT's Cement-Lock Technology to decontaminate dredged river sediments, to produce a salable end product from the sediments, and to determine some of the important physical and chemical properties of the end product.

Program Success Criteria

The following criteria were established to measure the success of this research program:

- Contaminated sediments to be treated by the Cement-Lock Technology (to destroy organics and immobilize metals) must not consume fresh modifiers more than 50 weight percent of sediments
- Blended cement produced from contaminated sediments must pass the EPA TCLP test for appropriate priority metals
- Compressive strength of blended cement produced from contaminated sediments must pass ASTM standards for blended cement.

This report presents the results of an experimental program conducted by IGT under a contract with GRI for "Decontamination and Beneficial Reuse of Contaminated River Sediments

Using Cement-Lock Technology." Construction Technology Laboratories, Inc. (CTL, Skokie, IL - the research arm of the Portland Cement Association) was a subcontractor to IGT on the project. CTL performed standard compressive strength tests on the Cement-Lock end product.

CEMENT-LOCK TECHNOLOGY DESCRIPTION, BENEFITS, AND LIMITATIONS

The Cement-Lock Technology is an advanced management system for contaminated soils, sediments, sludges, concrete and building debris, and similar wastes. This technology systematically puts every ounce of waste to beneficial use. The Cement-Lock Technology converts the waste into a construction-grade blended cement, which can be sold in the open market. All secondary and fugitive waste streams associated with typical waste processing are completely eliminated. Additional beneficial products that could be produced depend upon the waste stream and its composition. In the case of contaminated sediments, in addition to producing blended cement, it could also produce steam for power generation.

The beneficial reuse of wastes through Cement-Lock Technology application adds many advantages to conventional waste processing. These include a) additional revenues generated from the sale of blended cement; b) savings from the elimination of the need to landfill the wastes, including sizable quantities of residues from conventional processing; c) ability to maintain extremely low tipping fees because of secondary revenue streams; and d) environmental superiority when compared to any conventional processing.

The Cement-Lock Technology is not to be confused with either the cement manufacturing plants or incineration technologies. With only the final product as a common element, the Cement-Lock Technology bears no other relationship to the manufacture of portland cement. The Cement-Lock Plant is considerably simpler than a portland cement manufacturing plant and bears little or no resemblance to the actual complex cement plant. Unlike a cement plant, the Cement-Lock Technology does not have an extensive sizing requirement for the materials being processed, it does not have the extreme temperature requirements of a cement plant, it does not produce any waste stream (such as cement kiln dust), it does not require complex energy management to save energy, it does not produce high NO_x emissions, it does not have stringent requirements for materials of construction, and finally the starting raw materials are entirely different.

Nor is the Cement-Lock Technology an incineration process either. It is rather a thermo-chemical manufacturing process that utilizes inherent properties of wastes as feedstocks for producing economically attractive end products (Figure 2).

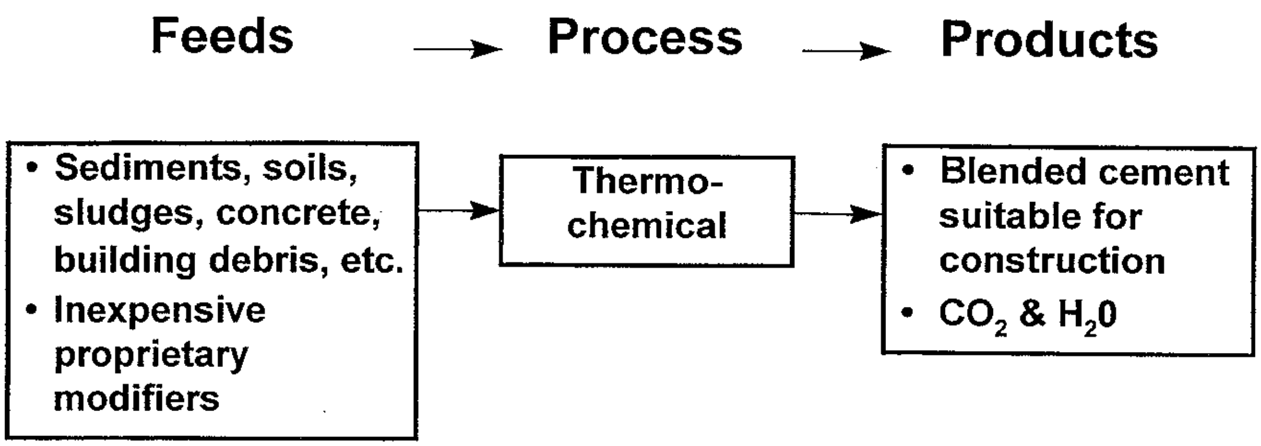


Figure 2. CEMENT-LOCK = MANUFACTURING PROCESS

In the Cement-Lock Technology (Figure 3) contaminated sediments dredged from harbors or river bottoms are reacted in a melter with suitable modifiers in proportions required for producing an environmentally friendly material called Ecomelt™. Ecomelt is a decontaminated and environmentally stabilized product that possesses latent cementitious properties. These properties are utilized to convert the Ecomelt into blended cement, which has compressive strength properties exceeding those required for conventional portland cement. The quantity of modifiers, which depends upon sediments composition, is typically less than twenty weight percent of the sediments. The melter for carrying out this process is operated at temperatures up to about 2550°F (1399°C), or lower temperatures sufficient to melt the sediments-modifier mixture. In the presence of excess air at these temperatures, organic contaminants originally present in the sediments are completely destroyed and converted to innocuous carbon dioxide and water. Chlorine present in some of the organic compounds (such as dioxins, furans, and PCBs) is converted to hydrogen chloride (HCl), which is either sequestered in the melt or readily scrubbed from the flue gas by using a solid media filter comprised of calcium oxide operating at 1000° to 1100°F (538° to 593°C).

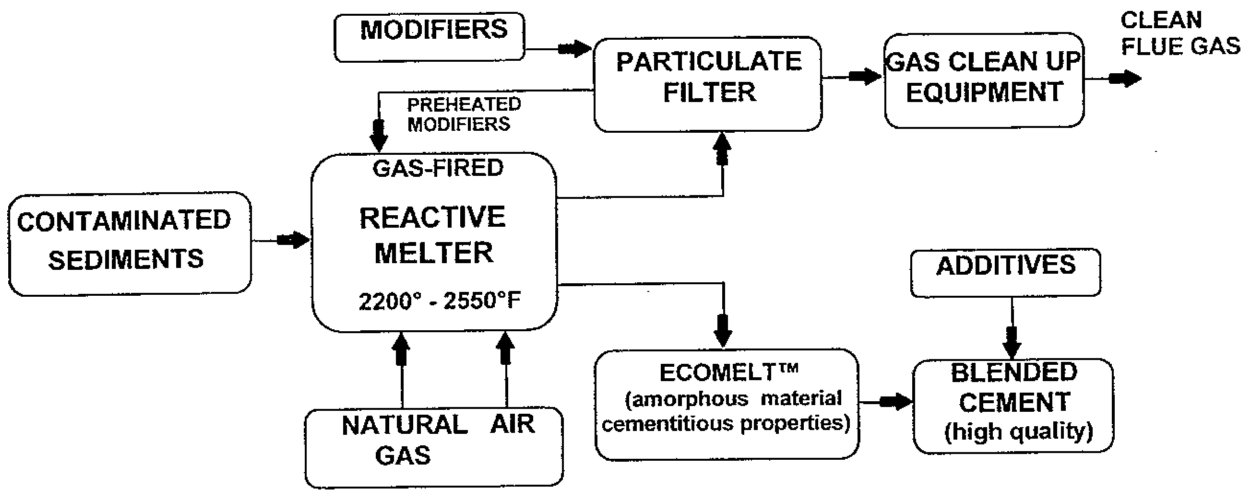


Figure 3. CEMENT-LOCK TECHNOLOGY SCHEMATIC DIAGRAM FOR PROCESSING CONTAMINATED SEDIMENTS

Heavy metals present in the sediments are locked into the cement matrix (predominantly calcium-alumino silicates) to completely immobilize them. The melt containing immobilized metals is rapidly quenched to prevent crystallization and subsequently pulverized and mixed with an additive to yield blended cement. This product can be put to beneficial use in the construction industry with a ready market. Volatilized heavy metals as well as non-destroyed organics are recovered from the gas and recycled to the melter for complete assimilation in the process. Highly volatile metals, such as mercury and arsenic, are removed from the off-gas by amalgamating them with affinity metals distributed over a filter element.

Hot flue gas emanating from the melter is used to preheat the modifiers before they enter the melter. The modifiers also act as a filter to remove particulates from the flue gas. The flue gas is quickly cooled from about 2550° to 1600°F (1399° to 871°C) in the filter. Additional heat can be recuperated from the flue gas to raise steam.

The Cement-Lock Technology does not generate any secondary hazardous waste streams. The streams exiting the process are: 1) blended cement as a primary product, 2) a solid stream consisting of $CaCl_2$ and $CaSO_4$ (with small amounts of NaCl and KCl) as a secondary product usable as winter road salt, 3) CO_2 and water vapor, and 4) an amalgam of Hg as a useful secondary resource for recovery of Hg.

The advantages of the Cement-Lock Technology include:

a. It can treat all types of contaminated (organic as well as inorganic) materials regardless of its concentration.

b. It treats all types of soils - from sandy to clayey and silty.

c. No feed pretreatment is required.

d. No secondary hazardous waste streams are generated from the process.

e. It is an environmentally friendly technology.

f. It is a simple - yet effective process.

The following benefits accrue from deployment of the Cement-Lock Technology:

- It provides a sound basis for destroying harmful organic contaminants and immobilizing inorganic contaminants present in dredged sediments.
- It utilizes dredged sediments to produce a widely used salable product (blended cement) thereby conserving land-based resources which would have otherwise been deployed.
- It helps keep the nation's waterways navigable and safe without negatively impacting the environment.
- It helps defray the costs of sediments cleanup whereby resources could be deployed elsewhere for environmental restoration.
- It does not discharge environmentally harmful pollutants into the atmosphere.
- The product from sediments treatment is environmentally safe to use in the construction industry.
- Although the technology is thermo-chemical in nature, it offers much superior destruction of organic contaminants than any known incineration technology.

The Cement-Lock Technology can also be applied to remediation of contaminated soils at Superfund sites as well as manufactured gas plant sites and recycling of contaminated concrete. Besides cleaning up waste sites, the technology offers a great potential for additional job creation and economic enrichment in affected communities.

The technology has no known limitation in terms of application with respect to types of contaminants or the levels of contaminants. It has no limitations on water content of the waste stream either.

The Cement-Lock Technology can handle a variety of feedstocks; these feedstocks are summarized in Tables 1 and 2. Primary feedstocks (Table 1) include sediments, soils, sludges, concrete, fly ash, bottom ash, cement kiln dust, etc. Secondary feedstocks (Table 2), such as petroleum coke, used rubber tires, refinery bottoms, paper mill sludge, etc., contain fuel value and can be co-processed with primary feedstocks.

Table 1. PRIMARY FEEDSTOCK CANDIDATES FOR CEMENT-LOCK TECHNOLOGY

Feedstock	Category	Water Content Limit, wt %	Limit on Type and Extent of Organic Contaminants	Limit on Type and Extent of Inorganic Contaminants
Dredged estuarine sediments, Cat. I, II, III	Nonhazardous	Up to 70%	None	None
Contaminated soil from Superfund sites	Hazardous	n/a	None	None
Contaminated soil from town gas sites	Nonhazardous	n/a	None	n/a
Sludge from Superfund sites	Hazardous	Up to 70%	None	None
PCB-Contaminated sediments	Hazardous	Up to 70%	None	n/a
Construction debris	Hazardous	n/a	None	None
Contaminated concrete from DOE and DOD decommissioning	Hazardous	n/a	None	None
Fly ash and bottom ash	Hazardous & Nonhazardous	n/a	n/a	None
Spent FCC catalyst	Hazardous	n/a	None	None
Cement kiln dust	Hazardous	n/a	n/a	None

Table 2. SECONDARY FEEDSTOCK CANDIDATES FOR CEMENT-LOCK TECHNOLOGY

Waste Stream	Category	Reason for Being a Waste Stream	Limit on Organic Contaminants for Cement-Lock Application	Limit on Inorganic Contaminants for Cement-Lock Application
Used rubber tires	Nonhazardous	Difficult to burn in combustion systems, produces dioxins, furans, SOx, etc.	None	None
Municipal sewage sludge	Hazardous	High metal content	None	None
PCB-Contaminated transformer oils	Hazardous	PCB content	None	n/a
Refinery bottoms	Nonhazardous	High sulfur and metals	None	None
Petroleum coke	Nonhazardous	High sulfur and vanadium	None	None
Coal washings (Culm)	Nonhazardous	High sulfur, high ash	None	None
Paper mill sludges	Hazardous	Dioxins	None	None
Gas from sewage treatment plant	Nonhazardous	high sulfur, low calorific value	None	n/a
Waste organic stream from chemical plant	Hazardous & Nonhazardous	Difficult to dispose	None	None

BENCH-SCALE TREATMENT OF RIVER SEDIMENTS

This section describes characteristics of the river sediments, details of the bench-scale experimental program conducted, and testing and evaluation of the Cement-Lock end product, namely, blended cement.

Sample Description and Characterization

A representative sample (5-litre container; about 16 lbs) of Detroit River sediments from the Rouge Turning Basin site was obtained for the bench-scale treatability study in the Cement-Lock Process.

Moisture Content

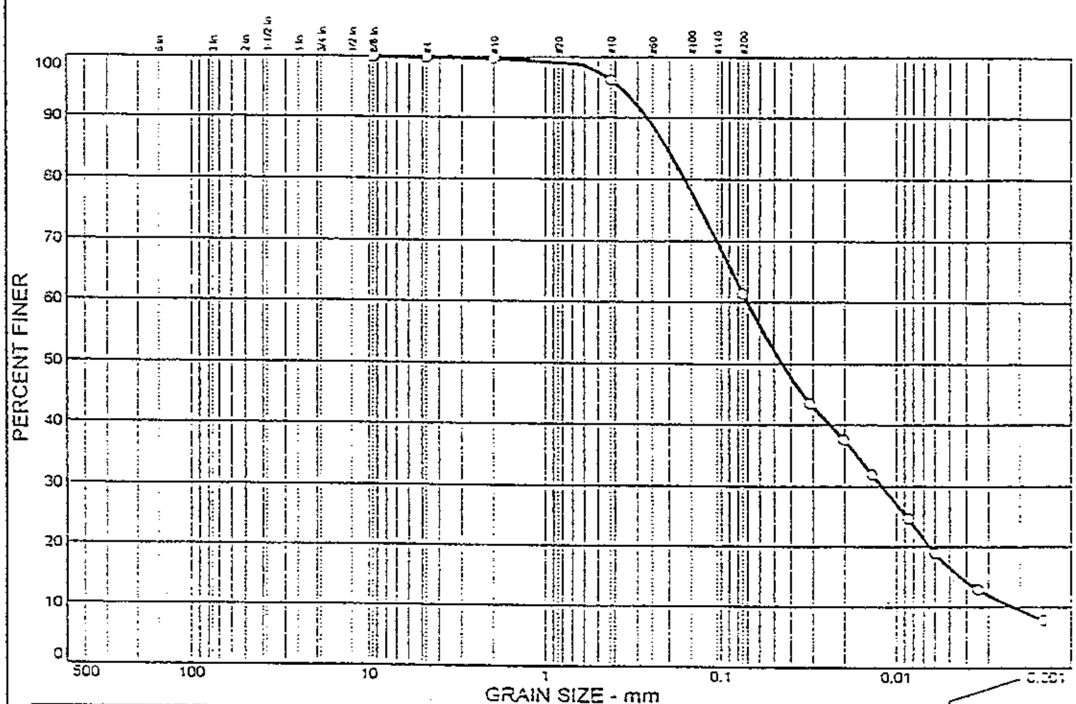
Most of the sediments sample received was weighed and placed in clean and dry containers of known weight, dried in an oven at 105°C to complete dryness, and the final weight recorded. The moisture content was determined from the weight loss; the as-received material contained 41.3 percent moisture. The dried material was ground in a ring-and-puck grinder. The ground material was then well mixed. A portion of this ground material was transferred to CTL for preparation of blended cement.

Particle Size Analysis

The particle size distribution of the dried sediments is given in Figure 4. It contains 0.3% gravel, 38.5% sand, 52.0% silt, and 9.4% clay. The median particle size (D_{50}) is 45 μm.

Chemical Analysis (ICPAES Method)

A small representative specimen (10 grams) was ground to pass 100 mesh, and analyzed at IGT by inductively coupled plasma atomic emission spectroscopy (ICPAES) for its chemical composition. The analysis, expressed as oxides, is given in Table 3. The sediments are comprised largely of silica, iron oxide, alumina, and calcium oxide (48.74%, 11.68%, 6.43%, and 5.43%, respectively).



% + 3"	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.1	0.2	3.5	34.8	52.0	9.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	99.9		
#10	99.7		
#40	96.2		
#200	61.4		

Soil Description

Sandy silt

Atterberg Limits

PL= LL= NP PI=

Coefficients

D_{85}= 0.207 D_{60}= 0.0707 D_{50}= 0.0449
D_{30}= 0.0122 D_{15}= 0.0044 D_{10}= 0.0022
C_u= 31.76 C_c= 0.95

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Moisture Content: 80.9%

Figure 4. PARTICLE SIZE DISTRIBUTION OF DREDGED RIVER SEDIMENTS

Table 3. MAJOR/MINOR OXIDE COMPOSITION* OF DREDGED RIVER SEDIMENTS

Component	Weight %
SiO_2	48.74
Al_2O_3	6.43
Fe_2O_3	11.68
CaO	5.43
MgO	2.08
SO_3	1.34
Na_2O	< 0.12
K_2O	NA
TiO_2	0.24
P_2O_5	< 0.16
L.O.I. (750°C)	18.90
Other (by diff.)	> 5.16
Total	100.00

* moisture-free basis.

Trace Elements Analysis (Atomic Absorption Method)

The trace element analysis of the river sediments is given in Table 4.

Table 4. TRACE ELEMENT ANALYSIS OF DREDGED RIVER SEDIMENTS

Element	mg/kg (dry)
Arsenic	7.8
Barium	157
Cadmium	9.5
Chromium	138
Copper	180
Iron	37,000
Mercury	0.55
Manganese	710
Nickel	46
Lead	218
Zinc	610

Raw-Mix Formulation

Based on prior experience with estuarine sediments from the New York/New Jersey harbor and recycle concrete, and the chemical composition and the physical characteristics of the river sediments sample, a raw-mix formulation was developed for producing a cementitious material (Ecomelt). The criteria for determining the raw-mix formulation were to -

- Maximize the use of sediments in the raw mix
- Minimize the use of modifiers
- Have a low melting point of the mixture
- Produce Ecomelt with high degree of amorphosity
- Produce Ecomelt with adequate latent cementitious properties.

Thus, a formulation with the potential of maximizing the sediments use and minimizing the addition of modifiers was developed. The formulation contained 83% dried sediments and 17% inexpensive modifiers.

Ecomelt Production

The mixture of dried sediments and modifiers was hand-mixed in a mortar and pestle, loaded into an Inconel crucible, and fired in a muffle furnace at a temperature of 2260°F (1238°C) for about one hour duration. The melt was then withdrawn from the furnace, and quickly quenched in cold water to maximize amorphosity and to prevent any crystallization. The melt (referred to as Ecomelt) was dried in air. About 4 pounds of the sediments were processed in several batches. The Ecomelt from the different batches was then well mixed.

One pound of sediments (moisture-free) yields approximately one pound of Ecomelt.

Determination of Amorphous Phase in Ecomelt

The crystalline phases present in the untreated sediments are non-reactive and can only act as fillers when used with cement. Thermo-chemical treatment by the Cement-Lock Technology converts these phases to reactive amorphous components that are capable of forming a complementary cementitious phase — calcium-silicate-hydrate — when blended with portland cement and hydrated with water. The Ecomelt was examined for the level of amorphosity using an optical microscope with transmitted light and x-ray diffraction procedures. The procedures determined the crystalline phase as well as the amorphous phase present in the Ecomelt.

Microscopic Test

The Ecomelt was finely ground and a small sample was mounted on a glass slide. The sample was examined under an optical microscope with transmitted light to determine the level of amorphosity. Under ordinary light, both amorphous as well as crystal phases are visible, however, under cross-polar light, the amorphous phase is not visible. The amorphous phase in the Ecomelt was visually estimated to be over 85 percent.

X-Ray Diffraction (XRD) Test

The Ecomelt was also examined for its amorphosity using the x-ray diffraction (XRD) method. The XRD pattern of the Ecomelt (Figure 5) appears to be typical of an amorphous material showing no crystalline peaks.

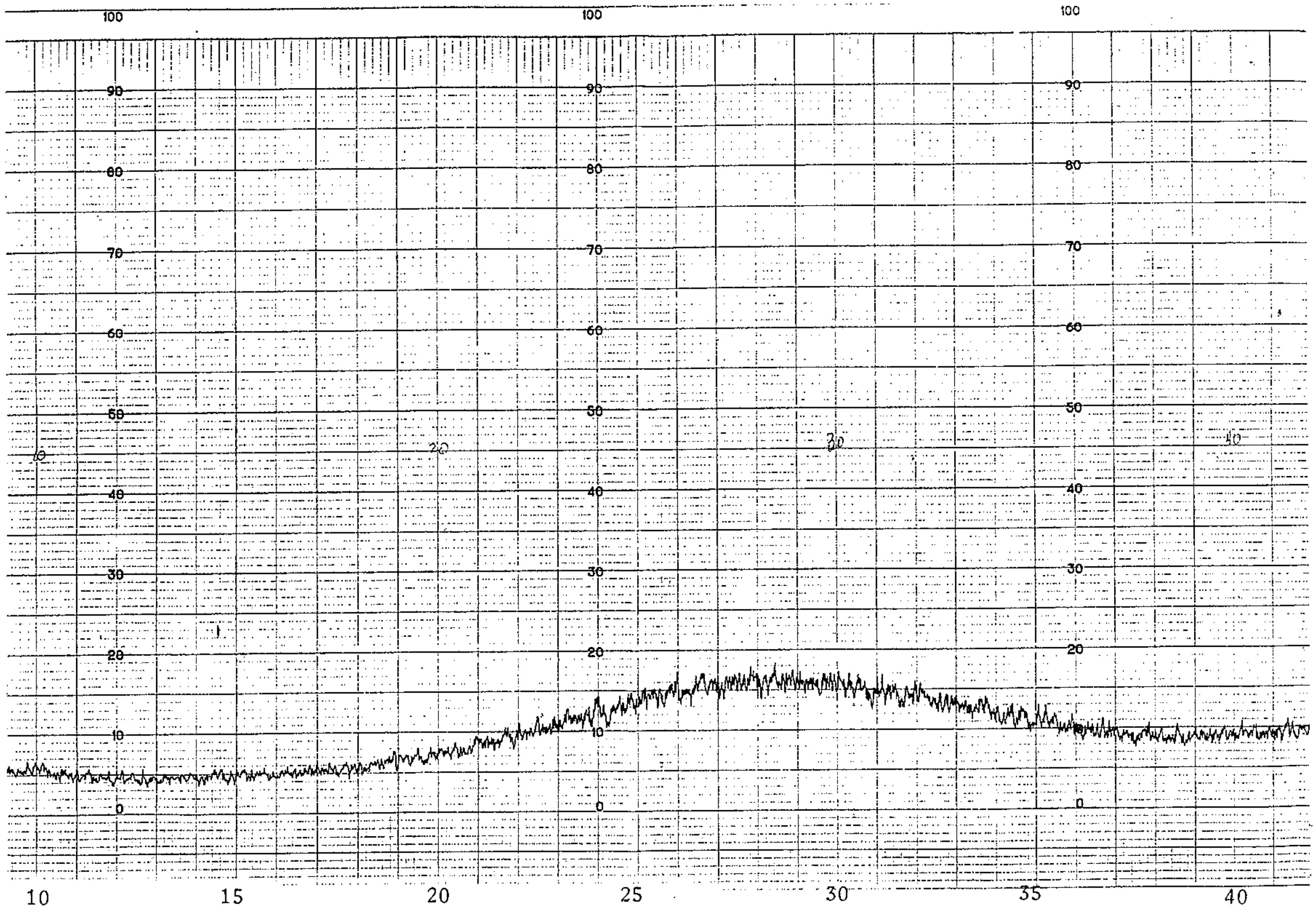


Figure 5. XRD PATTERN OF ECOMELT SHOWING AMORPHOUS PHASE

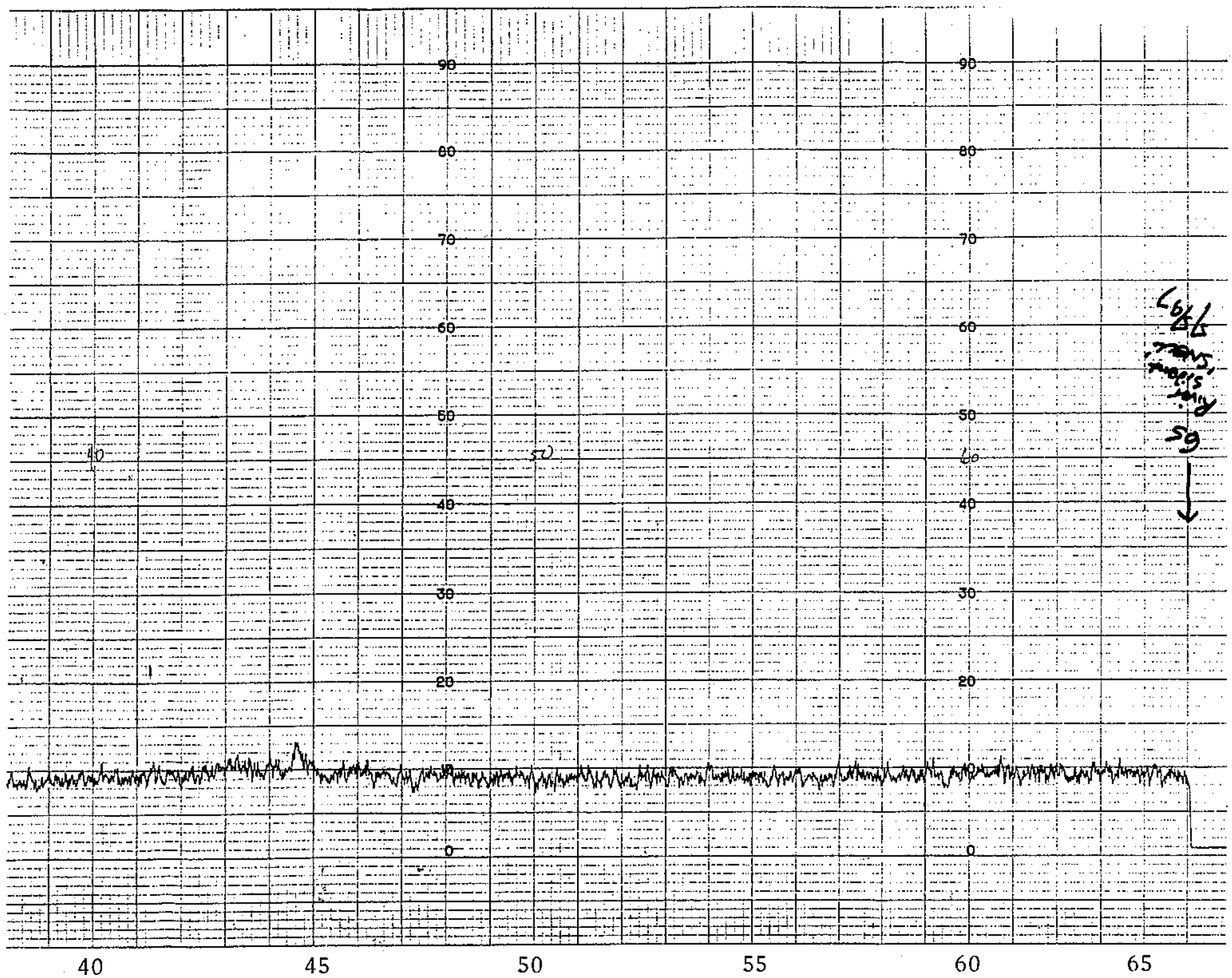


Figure 5 (Cont.). XRD PATTERN OF ECOMELT SHOWING AMORPHOUS PHASE

Production of Blended Cement

In order to test the Ecomelt as a suitable component for blended cements, IGT opted to use ASTM (American Society for Testing and Materials) Standard C 595. This standard requires the Ecomelt to be blended with portland cement. Therefore, the Ecomelt was finely ground in a ball mill to a Blaine fineness of about 4000 cm^2/g. The ground material was then blended with Type I portland cement in the proportion of 40% Ecomelt and 60% portland cement as specified for Type IP and P blended cement per ASTM C 595 specifications. Type IP is a portland-pozzolan cement used in concrete for general construction; Type P is a portland-pozzolan cement for concrete construction where high strength at early age is not required. Maximum use of the pozzolan (40% by mass as specified by ASTM C 595) was a deliberate effort to minimize the use of portland cement while still aiming for strength properties comparable to those of Type IP and P cement. No activator (performance enhancing additive) was used in the blends.

Testing and Evaluation of Blended Cement

The blended cement product was analyzed for oil and grease, total metals, total base neutrals, PCBs, and TCLP base neutrals. The blended cement product was also evaluated for compressive strength as per the ASTM specifications C 595 and C 1157.

Organic Destruction

The oil and grease, PAHs, and PCBs contents of the untreated sediments were 18,000 mg/kg, 51.2 mg/kg, and 1,100 μg/kg, respectively. In the blended cement, the contaminants were below the detection limit of the analytical procedures used, indicating that these contaminants were completely destroyed in the process (Table 5). The organic compounds present in the untreated sediments and blended cement are given in Table 6.

Table 5. DESTRUCTION OF ORGANIC CONTAMINANTS BY CEMENT-LOCK TECHNOLOGY

Contaminant	Untreated Sediments	Blended Cement	DRE*
	mg/kg		
Oil & Grease	18,000	< D.L.**	> 99.99
PAHs	51.2	< D.L.	> 99.99
	μg/kg		
PCBs	1,100	< D.L.	> 99.99

* Destruction and removal efficiency.
** Less than the detection limit of the analytical procedure used.

Table 6. COMPARISON OF ORGANIC COMPOUNDS IN UNTREATED SEDIMENTS AND BLENDED CEMENT PRODUCT

Compound	Untreated Sediments Feed*	Blended Cement Product*
bis (2-Chloroethyl) ether	BDL**	BDL
1,3-Dichlorobenzene	BDL	BDL
1,4-Dichlorobenzene	BDL	BDL
1,2-Dichlorobenzene	BDL	BDL
Bis (2-Chloroisopropyl) ether	BDL	BDL
N-Nitroso-di-n-proply amine	BDL	BDL
Hexachloroethane	BDL	BDL
Nitrobenzene	BDL	BDL
Isophorone	BDL	BDL
Bis (2-Chloroethoxy) methane	BDL	BDL
1,2,4-Trichlorobenzene	BDL	BDL
Naphthalene	3,300	BDL
Hexachlorobutadiene	BDL	BDL
2-Chloronaphthalene	BDL	BDL
Dimethyl phthalate	BDL	BDL
Acenaphthylene	470	BDL
2,6-Dinitrotoluene	BDL	BDL
Acenaphthene	1,200	BDL
2,4-Dinitrotoluene	BDL	BDL
Fluorene	1,200	BDL
Diethyl phthalate	BDL	1,000
4-Chlorodiphenyl ether	BDL	BDL
N-Nitrosodiphenyl amine	BDL	BDL
1,2-Diphenylhydrazine	BDL	BDL
4-Bromodiphenyl ether	BDL	BDL
Hexachlorobenzene	BDL	BDL
Phenanthrene	6,900	BDL
Anthracene	1,500	BDL
Di-n-butyl phthalate	910	220
Fluoranthene	7,300	BDL
Pyrene	7,600	BDL
Butyl benzyl phthalate	BDL	98
Benzo(a)anthracene	3,300	BDL
Chrysene	4,000	BDL
bis (2-ethylhexyl) phthalate	10,000	4,700
Di-n-octyl phthalate	510	BDL

Table 6 (Cont.). COMPARISON OF ORGANIC COMPOUNDS IN UNTREATED SEDIMENTS AND BLENDED CEMENT PRODUCT

Compound	Untreated Sediments Feed*	Blended Cement Product*
Benzo(b)fluoranthene	3,300	BDL
Benzo(k)fluoranthene	3,300	BDL
Benzo(a)pyrene	3,600	BDL
Indeno(1,2,3-c,d)pyrene	1,900	BDL
Dibenzo(a,h)anthracene	BDL	BDL
Benzo(g,h,i)perylene	2,300	BDL
Aroclor 1242 (PCB)	1,100	BDL
Aroclor 1254 (PCB)	BDL	BDL
Aroclor 1260 (PCB)	BDL	BDL
Aroclor 1016 (PCB)	BDL	BDL
Aroclor 1221 (PCB)	BDL	BDL
Aroclor 1232 (PCB)	BDL	BDL
Aroclor 1248 (PCB)	BDL	BDL
Aroclor 1262 (PCB)	BDL	BDL
Aroclor 1268 (PCB)	BDL	BDL

* 1.0 lb of moisture-free sediments produced 2.53 lb of blended cement.

** Below detection limit of the analytical instrument used.

Metal Immobilization

The results of the EPA TCLP procedure conducted on the blended cement product are summarized in Table 7 along with the regulatory limits. The table shows that the leachability of priority metals from the blended cement is significantly below the regulatory limit for each of the metals.

Table 7. METAL IMMOBILIZATION IN BLENDED CEMENT PRODUCED FROM RIVER SEDIMENTS

Metal	Untreated Sediments	TCLP* Blended Cement	TCLP* Regulatory Limit
	-mg/kg (Dry)-	mg/L	mg/L
Arsenic	7.8	< 0.01**	5
Cadmium	9.5	< 0.002	1
Chromium	138	< 0.072	5
Copper	180	< 0.01	NA
Lead	218	< 0.01	5
Mercury	0.55	< 0.0004	0.2

* Toxicity Characteristic Leaching Procedure.
** Less than the detection limit of the analytical procedure used.

Trace Metals in Blended Cement

The trace metals present in the blended cement along with the range of these metals present in conventional portland cement (Portland Cement Association, 1992) is given in Table 8. The table shows that these metals are present in the blended cement within acceptable cement industry limits.

Table 8. TRACE METALS IN CEMENT-LOCK BLENDED CEMENT AND PORTLAND CEMENT

Element	Cement-Lock Blended Cement	Portland Cement Range	
	mg/kg		
Mercury	< 0.05*	< 0.001	0.039
Selenium	NA	0.62	2.23
Cadmium	< 2	0.03	1.12
Lead	< 5	1	75
Silver	NA	6.75	19.9
Arsenic	9.0	5	71
Barium	NA	91	1402
Chromium	200	25	422
Nickel	60	10	129

* Less than the detection limit of the analytical procedure used.

Compressive Strength

Using the blended cements prepared above and Ottawa sand and water, a mortar mix was prepared by CTL (the research arm of the Portland Cement Association) in accordance with the ASTM C 109 standard procedure. The amount of mixing water was adjusted to produce mortars with a flow of 110±5. The mortars were cast as 2-inch cubes, and left overnight in a moist room at ambient temperature. Thereafter, the cubes were demolded and cured in saturated lime-water solution. These cubes were tested for compressive strength at 3, 7, and 28-day intervals as specified by the ASTM procedure; the results are shown in Table 9. The table shows that the compressive strength of the mortar cubes exceeds the ASTM requirements for blended cement (C 595, C 1157) as well as for portland cement (C 150). It should be noted that the blended cement did not require the use of any activator (performance enhancing additive) to yield these high strengths. The results presented are the average of three separate strength tests for each time period. The reported compressive strength for the 3-day period is an average of 2380, 2180, and 2178 psi; the reported strength for the 7-day period is an average of 2815, 2985, and 2925 psi; the reported strength for the 28-day period is an average of 4650, 4400, and 4725 psi.

Table 9. COMPRESSIVE STRENGTH OF BLENDED CEMENT PRODUCED FROM RIVER SEDIMENTS

Test Period	River Sediments Based Blended Cement	ASTM Requirements		
		Blended Cement		Portland Cement
		C 595	C 1157	C 150
--days--	psi			
3	2245	1890	1740	1740
7	2910	2900	2900	2760
28	4600	3480	NS*	4060

*NS = not specified.

ACHIEVEMENT OF PROGRAM SUCCESS CRITERIA

The following criteria were established to measure success of this research program:

- Contaminated river sediments to be treated by the Cement-Lock Technology (to destroy organics and immobilize metals) must not consume fresh modifiers more than 50 weight percent of the sediments
- Blended cement produced from the contaminated river sediments must pass the EPA TCLP test for appropriate priority metals
- Compressive strength of blended cement produced from contaminated river sediments must pass ASTM Standards for blended cement.

In this program, the following were demonstrated:

The Cement-Lock Technology is suitable for treatment of contaminated river sediments. The fresh modifiers added were only 20 weight percent of the sediments (i.e., significantly less than 50 weight percent of the sediments).

The EPA TCLP procedure conducted on the blended cement showed the amount of priority metals leached from the blended cement were significantly below the regulatory limits (see Table 7). This demonstrates that the metals present in the contaminated river sediments can be immobilized in the final product.

As shown in Table 8, the 3, 7, and 28-day compressive strengths of the blended cement were greater than those required for general purpose cement (per ASTM C 595, C 1157, and C 150 specifications). It is significant to note that these strengths were achieved without using any activators (performance enhancing additives).

The above results firmly establish that the current program was successful. The technology is now ready for evaluation at a larger scale of operation, specifically at a pilot-scale operation.

IMPACT OF TECHNOLOGY SCALE-UP ON DESTRUCTION AND REMOVAL EFFICIENCY

Thus far, the Cement-Lock Technology has been tested on a scaled-up basis with dredged sediments from the Newtown Creek (New York) estuary only. Continuous operation of the Cement-Lock Technology was achieved in an integrated pilot plant facility at feed rates averaging one ton of untreated sediments per day. The impact of scale-up on the destruction and removal efficiency (DRE) of organic contaminants, metals leachability (TCLP), and compressive strength are presented in Tables 10, 11, and 12, respectively. Table 10 shows the DRE of organic contaminants and Table 11 shows the results of TCLP analysis for the blended cements produced from the bench-scale tests and the pilot-scale test. Table 12 indicates that the strength of the cement also improved in the pilot-scale processing. Therefore, it can be concluded that there is no significant impact of the technology scale-up on the DRE of the organic contaminants, metal leachability, and product quality for contaminated estuarine sediments. A similar trend is expected from the treatment of contaminated river sediments.

Table 10. COMPARISON OF ORGANIC DESTRUCTION IN BENCH-SCALE AND PILOT-SCALE UNITS FOR DREDGED ESTUARINE SEDIMENTS
(Newtown Creek Estuary Sediments)

Contaminant	Untreated Sediments Lab-Scale	Untreated Sediments Pilot-Scale	Blended Cement Lab-Scale	Blended Cement Pilot-Scale	DRE* Lab-Scale	DRE* Pilot-Scale
	mg/kg (dry)				%	
PAHs	116	370	0.3	0.22	99.24	99.93
	µg/kg (dry)					
PCBs	5,270	8,585	0.75	< D.L.**	> 99.96	> 99.99
	ng/kg (dry)					
2,3,7,8-TCDD/TCDF	381	262	< D.L.	< D.L.	> 99.99	> 99.99
Total TCDD/F	2,620	2,871	< D.L.	< D.L.	> 99.99	> 99.99
Total PeCDD/F	3,231	4,363	< D.L.	< D.L.	> 99.99	> 99.99
Total Hx/Hp/OCDD/F	38,945	34,252	18	< D.L.	99.88	> 99.99

* Destruction and removal efficiency.
** Less than the detection limit of the analytical procedure used.

Table 11. COMPARISON OF TCLP RESULTS ON BLENDED CEMENT PRODUCED IN BENCH-SCALE AND PILOT-SCALE UNITS FROM DREDGED ESTUARINE SEDIMENTS
(Newtown Creek Estuary Sediments)

Metal	Untreated Sediments Lab-Scale	Untreated Sediments Pilot-Scale	TCLP* Blended Cement Lab-Scale	TCLP* Blended Cement Pilot-Scale	TCLP* Regulatory Limit
	mg/kg (dry)		mg/L		
Arsenic	33	39	< 0.1**	< 0.005	5
Barium	--	--	< 0.5	--	100
Cadmium	37	27	< 0.01	< 0.001	1
Chromium	377	298	0.2	0.15	5
Lead	617	542	< 0.05	< 0.002	5
Mercury	1.3	2.9	< 0.001	< 0.0004	0.2
Selenium	<3.2	6.2	< 0.1	< 0.003	1
Silver	18	13	< 0.01	< 0.001	5

* Toxicity Characteristic Leaching Procedure.
** Less than the detection limit of the analytical procedure used.

Table 12. COMPARISON OF COMPRESSIVE STRENGTH OF BLENDED CEMENT PRODUCED IN BENCH-SCALE AND PILOT-SCALE UNITS FROM DREDGED ESTUARINE SEDIMENTS

(Newtown Creek Estuary Sediments)

Test Period	Blended Cement		ASTM Requirements: Blended Cement		ASTM Requirements: Portland Cement
	Lab-Scale	Pilot-Scale	C 595	C 1157	C 150
--days--	psi				
3	1950	2230	1890	1740	1740
7	2730	2885	2900	2900	2760
28	4620	5270	3480	NS*	4060

*NS = not specified.

ENVIRONMENTAL IMPACT

This section discusses some of the anticipated environmental, health, and safety concerns that could arise during Cement-Lock plant operations to treat dredged river sediments.

Based on the bench-scale tests, river sediments treated by the Cement-Lock process are fully expected to meet all applicable regulatory requirements of the U.S. EPA. The most significant test and stabilization criteria that must be met by the Cement-Lock product is the EPA Toxicity Characteristic Leaching Procedure (TCLP; EPA Method 1311). Since the Cement-Lock Technology combines melting/vitrification with the production of cement to immobilize toxic metals, product from the Cement-Lock Technology is expected to meet the current and proposed EPA rules.

The Cement-Lock process itself is free of nuisance odors, noise, and occupational exposure hazards.

The final form in which the contaminants originally present in the dredged sediments will ultimately exit the Cement-Lock plant are summarized in Table 13. None of these streams are hazardous, or of long-term concern for the environment. All of the streams emanating from the process can be used or disposed of immediately.

Table 13. FATE OF SEDIMENT CONTAMINANTS IN CEMENT-LOCK PROCESS

Contaminant	Fate
Toxic Metals (if present):	
Ba, Cd, Cr, Cu, Pb, Ni, Ag, Se, Zn	Cement, stable
As, Hg	Adsorbed, solidified, and immobilized[1]
Polynuclear Aromatic Hydrocarbons, Organochlorine Pesticides, 2,3,7,8-Chlorine Substituted PCDD/PCDF Isomers:	
Organic Hydrogen	Demineralized water[2]
Cl, SOx	Salts, solidified, stable, some SOx in off gas[3]
Organic Nitrogen	Oxides of nitrogen, N_2[3] (off-gas)
Organic Carbon	CO_2 (off-gas)

1 Elements could be recovered.
2 Demineralized water is free released.
3 SO_x and NO_x expected to be within regulatory limits.

TRANSITION OF TECHNOLOGY FROM BENCH-SCALE TO FULL-SCALE OPERATION

The transition of the Cement-Lock Technology from bench-scale to full-scale operation for a new feedstock occurs in two stages. These stages are:

- Pilot Plant, which will process 5 to 10 cubic yards of material in a fully integrated system, replicating a commercial system. The pilot-plant data will be used for scale-up design as well as for obtaining permits. This facility is available and is described below.
- Full-scale facility is a modular facility consisting of one or several modules of about 100,000 cubic yards of sediments per year capacity. All the equipment needed for installing a full-scale plant are already available commercially.

Description of Pilot-Scale Facility

The Cement-Lock Technology has been demonstrated in both bench-scale and pilot-scale equipment with dredged sediments from the Newtown Creek estuary in New York. The tests demonstrated the effectiveness of the technology for decontaminating sediments and at the same time producing a valuable, salable product, blended cement. Laboratory-scale tests have also been conducted with contaminated concrete as well as contaminated river sediments (this report) to convert them to blended cement.

This section describes in detail the existing pilot plant facilities that are available to ENDESCO, Cement-Lock Group, L.L.C., and IGT for conducting a demonstration with river sediments. The rotary kiln-type Ecomelt generator, used for the pilot-scale testing of the Cement-Lock Technology with dredged estuarine sediments, was built by ABB Combustion Engineering.

The pilot plant facilities are located in Golden, Colorado. The feed capacity of the pilot plant is in the range of 100 to 300 pounds per hour, depending on moisture content of the feed material. The pilot plant (Figure 6) consists of four sections: a Denver Holoflite conveyor heated with a hot oil system for pre-drying the material, a 2-foot-diameter by 6.5-foot-long refractory-lined rotary kiln, a 21-inch-diameter by 24-foot-long refractory-lined secondary combustion chamber (SCC), and a gas-emission treatment system consisting of a quench tower for cooling the gas with

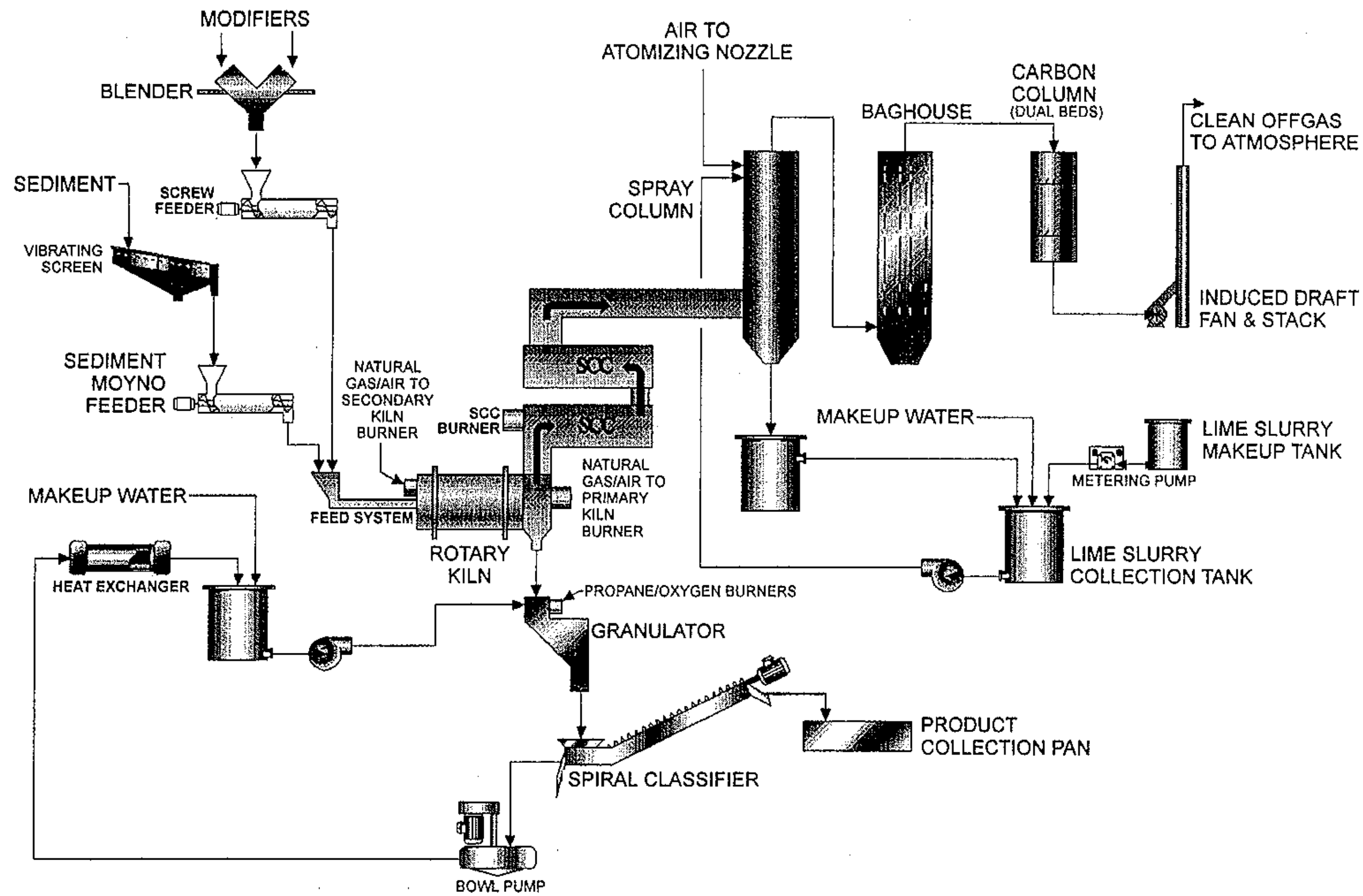


Figure 6. PROCESS FLOW DIAGRAM OF CEMENT-LOCK PILOT PLANT

a lime solution, a fabric-filter baghouse for dust control, and a two-bed absorption column for final emission control. The SCC is divided into two separate 12-foot-long sections on a horizontal plane. A draft fan provides vacuum control throughout the system.

The pilot plant is instrumented to facilitate control and to generate design data. System instrumentation includes:

- Six thermocouples which measure temperature in the kiln, SCC, quench tower, baghouse, and absorption column
- Temperature controllers which regulate air and natural gas flow to the burner systems
- Magnehelic gauges which measure pressure throughout the system and indicate differentials across orifice meters to measure air and natural gas flows
- A continuous emission monitor (CEM) which measures O_2, CO_2, CO, SO_2, O_2, NO_x, and total hydrocarbons (THC) in the SCC exhaust gas.

A Denver Equipment D0710-4 Holoflite is used to predry the sediments and flux prior to discharging to the kiln screw feeder (This step is generally not necessary). The vapors from the predrier are vented into the SCC. The Holoflite is heated with a hot-oil boiler maintained at 400°F.

The kiln is lined with monolithic casting of Ultra Green 57 A, manufactured by A. P. Green. This refractory is an ultra-low cement, 57% alumina castable with an andalusite base for thermal shock resistance, and is suitable for temperatures up to 3,000°F. The casting is poured over a one-inch-thick layer of 1,900°F insulating board to reduce heat flow to the steel shell and is secured to the kiln shell with stainless steel anchors. The casting includes a dam six inches wide by two inches high on the feed end and a dam four inches wide by one inch high on the discharge end. The kiln's inside diameter is 2.08 feet, and the internal length is 6.5 feet.

The kiln is heated using the primary natural-gas-fired burner located opposite the feed end. A secondary natural-gas-fired burner located above the kiln feeder is used to reach the high temperatures needed to melt the sediments and flux materials in the kiln. The hot combustion gases generated by the burners are used to heat the dense refractory lining and the burden in the kiln. Combustion gases and any volatile matter released from the material in the kiln enter the SCC. The SCC is heated with a natural-gas-fired burner located directly past the kiln exhaust.

Hot gases and entrained solids from the SCC are quenched in a tower 21 inches in diameter by 7.5 feet in height. A recirculating lime solution is used to cool the gases in the quench tower. The pH of the solution is controlled by addition of a lime slurry to the recirculating lime solution tank. The cooled gases, at about 350°F, are filtered in a fabric-filter baghouse with a total surface area of 184 square feet. The clean gas is conveyed to a two-bed absorption column. Gas flow through the absorption column is downward. The beds are three feet in diameter and one foot deep. The beds are supported with a 14-mesh stainless steel screen on top of one-inch bar grating. The first bed contains pelletized Sorbalit® and the second bed contains American Norit R-1540 extruded activated-carbon pellets. The Sorbalit®, which is quite dusty, is placed upon about a one-inch layer of 3/8-inch ceramic balls placed on top of the screen, to minimize dust penetration into the carbon bed. The gases are vented to the atmosphere with an induced-draft fan. A manually controlled damper is used to maintain the required pressures in the system.

Process gases at the SCC exhaust duct are sampled and analyzed continuously for O_2, CO_2, CO, SO_2, NO_x, and THC. The gas sample is filtered and cooled to remove entrained particulate matter and water vapor before the gas enters the analyzer. The THC analyzer receives a filtered hot sample.

The sediments and flux are introduced into the kiln using a standard-pitch, variable-speed screw auger six inches in diameter and five feet long. The screw flights are kept full of material during operation to prevent air infiltration into the kiln through the flights.

The sediments are metered into the screw feeder hopper with a Robbins and Myers open-throat 2JS3 progressive cavity Moyno pump. In order to protect the pump, the sediment is screened at 1/4-inch using an 18-inch vibrating Sweco screen that discharges directly into the throat of the Moyno pump. Tramp materials like wood, stone, and plastic are picked off the screen. The modifiers and flux material are pre-blended before metering the blend into the screw feeder hopper, using a four-inch standard-pitch screw feeder.

A refractory-lined box, 18 inches long and with a 12-inch-square inside opening, is placed between the kiln discharge and the granulator. Propane/oxygen burners are positioned inside the box to provide a heat shield between the kiln discharge and the granulator. These burners are used to prevent the molten slag from freezing before the slag reaches the cold-water sprays inside the granulator. The granulated product is collected in an open-trough inclined screw and conveyed onto a pan on the operation deck. The product discharge of the granulator is submerged in water to provide a seal which prevents ambient air from entering the kiln discharge. Two high-velocity water spray nozzles inside the granulator are used to quench and granulate the molten slag as it drips from the kiln discharge. A 1/2-inch pipe with seven 3/16-inch holes along one side is used to flood the sloped bottom of the granulator with additional water. The quench water overflows the screw trough into a bowl pump. The water is cooled in a heat exchanger and recirculated.

The gas composition, kiln temperature, and two SCC temperatures are logged using a MOLYTEK data-acquisition system. All other data are manually recorded hourly on data log sheets, and notes on operations and problems are recorded in an operations logbook.

Any equipment needed for a pilot-scale demonstration can be easily added to the existing pilot plant.

Existing/Operating Large-Scale Facilities

One configuration of the Ecomelt generator/melter that can be used for producing molten Ecomelt from the sediments is a vertically oriented, refractory-lined cylinder. The Type "A" melter is constructed with water-wall cooling to minimize refractory thickness. A layer of frozen slag coats the internal walls of the melter to extend refractory life. The sediments and modifiers are fed into the melter through a port at the top of the melter. The energy required to melt the sediments and modifiers is supplied through a submerged lance, which is comprised of concentric tubes for feeding air and natural gas into the melt. The lance can be moved up or down depending upon the depth of the melt. Typically, air (or enriched air) is fed through the outer shell of the lance thereby cooling the lance somewhat. Natural gas is fed through the inner tube. Combustion products bubble vigorously throughout the melt. The flow of gas instills a circulating pattern through the melt ensuring complete mixing. During initial melter operation, the lance becomes coated with a layer of frozen slag, which significantly extends its life. When a lance must be replaced, however, a spare can be installed within about 30 minutes with minimal effort.

Such a reactive melter has been developed by Ausmelt Technology Corporation, and has been deployed in numerous commercial-scale applications in the metals smelting and processing industry. A list of applications, plant capacity, location, and plant status is presented in the Table 14.

A second type of Ecomelt generator is based on the rotary kiln; this generator has been used extensively in the past for a myriad of different applications including incineration and thermal desorption. ABB Combustion Engineering and Svedala have a long list of previous applications with rotary kiln installations (Tables 15 and 16, respectively). The pilot-scale test with dredged estuarine sediments was conducted recently in a rotary kiln operated in slagging mode.

Table 14. COMMERCIAL EXPERIENCE WITH TYPE "A" ECOMELT GENERATOR

Unit Capacity, ton/year	Location	Application	Status
7,500	Australia	Copper smelting	Pilot plant operation
15,000	The Netherlands	Tin smelting	Closed due to low metal price
105,000	Australia	Fuming ISF slag to produce Zn/Pb product	Operative
90,000	South Korea	Fuming Pb and Zn slag	Operative
30,000	Peru	Tin concentrate metallization	Operative
10,500	Zimbabwe	Copper, Pt-group metals	Operative
125,000	South Korea	Zn recovery from minerals	Operative
90,000	Germany	Primary and secondary Pb	In progress
120,000	Namibia	Primary Pb furnace	In progress

Table 15. RAYMOND™ ROTARY KILN SYSTEMS

CUSTOMER	EQUIPMENT	WASTE	THERMAL
BORG AUSTRAL BUENOS AIRES ARGENTINA 1996	MODEL 500 ROTARY KILN WITH FEED AND ASH SYSTEM, SCC, APC, FAN, STACK, CEM MODULAR INCINERATOR	RCRA AND TSCA COMMERCIAL WASTE	6.5 MMBTU/HR, KILN 5 MMBTU/HR, SCC
CALIFORNIA THERMAL TREATMENT SYSTEMS CALIFORNIA, U.S.A. 1986	DESIGN AND ENGINEERING NO.12 ROTARY KILN, SCC, FEED SYSTEM, ASH REMOVAL APC, FAN, STACK, AND TANKS. RCRA PERMIT RECEIVED. BUILDING PERMIT DENIED. PROJECT CANCELLED.	RCRA AND TSCA COMMERCIAL WASTE	30 MM BTU/HR, KILN 20 MM BTU/HR, SCC
CHEM-SECURITY CANADA 1990	NO.9 ROTARY KILN WITH FEED AND ASH SYSTEM, SCC, APC, FAN, AND STACK	RCRA AND TSCA COMMERCIAL WASTE	25 MM BTU/HR, KILN 15 MM BTU/HR, SCC
CHEMICAL WASTE MGMT TEXAS, U.S.A. 1989	MATERIAL HANDLING SYSTEM FOR THE ROTARY INCINERATOR	RCRA AND TSCA COMMERCIAL WASTE	NOT APPLICABLE
EASTMAN KODAK NEW YORK, U.S.A. 1994	SCC WITH BURNER SYSTEM AND EMERGENCY STACK	WASTE GAS	22 MM BTU/HR
ELI LILLY INDIANA, U.S.A. 1984	SCC, BURNER SYSTEM, EMER. STACK, AND GAS QUENCH	WASTE GAS	25 MM BTU/HR
ENVIROPACE HONG KONG 1991	NO.10 ROTARY KILN WITH SHREDDER, FEED AND ASH SYSTEM, SCC, BOILER, APC, FAN, AND STACK	RCRA AND TSCA COMMERCIAL WASTE	30 MM BTU/HR, KILN 36 MM BTU/HR, SCC
GENERAL MOTORS KANSAS, U.S.A. 1980	NO.5 ROTARY KILN WITH FEED AND ASH SYSTEM, SCC, APC, FAN, AND STACK	PAINT SLUDGE PLANT TRASH	3 MM BTU/HR, KILN 2 MM BTU/HR, SCC
HOUSTON CHEMICAL TEXAS, U.S.A. 1991	NO.15 ROTARY KILN WITH FEED SYSTEM, AND ASH REMOVAL. PROJECT ON HOLD	RCRA AND TSCA COMMERCIAL WASTE	90 MM BTU/HR, KILN
INDUSTRIAL SERVICE CORP. MISSOURI, U.S.A. 1986	NO.9 ROTARY KILN, SCC, FEED SYSTEM, ASH REMOVAL, APC, FAN, STACK, AND TANKS. EQUIPMENT BUILT, BUT PERMIT DENIED, PROJECT CANCELLED	RCRA AND TSCA COMMERCIAL WASTE	25 MM BTU/HR, KILN 15 MM BTU/HR, SCC

Table 15 (Cont.). RAYMOND™ ROTARY KILN SYSTEMS

CUSTOMER	EQUIPMENT	WASTE	THERMAL
MONSANTO (MPKC) THAILAND 1994	NO.6 ROTARY KILN WITH FEED AND ASH SYSTEM, SCC, APC, FAN, AND STACK	ABS PLASTICS, PLANT TRASH	12 MM BTU/HR, KILN 5 MM BTU/HR, SCC
NISSAN MOTORS TENNESSEE, U.S.A 1987	NO.7 ROTARY KILN WITH FEED AND ASH SYSTEM, SCC, BOILER, APC, FAN, STACK, AND TANKS	PAINT SLUDGE, PLANT TRASH	15 MM BTU/HR,KILN 15 MM BTU/HR,SCC
PEOPLES REPUBLIC OF CHINA JINZHOU, CHINA 1985	NO.9 ROTARY KILN WITH FEED AND ASH SYSTEM, BOILER, SCC, APC, FAN, AND STACK	MOTOR OIL FILTRATE	25 MM BTU/HR,KILN 15 MM BTU/HR,SCC
ROSS ENVIRONMENTAL OHIO, U.S.A 1984	NO.10 ROTARY KILN AND INLET HEAD	RCRA COMMERCIAL WASTE	40 MM BTU/HR,KILN
U.S.A DEPARTMENT OF AGRICULTURE MEXICO 1981	NO.6 ROTARY KILN WITH FEED AND ASH SYSTEM, BOILER, SCC, APC, FAN, AND STACK	BIOLOGICAL WASTE	6 MM BTU/HR, KILN 0.5 MM,BTU/HR,SCC
CONFIDENTIAL 1988	NO.7 ROTARY KILN WITH FEED AND ASH SYSTEM, SCC, APC, FAN, AND STACK MOBILE INCINERATOR	RCRA AND TSCA COMMERCIAL WASTE	15 MM BTU/HR, KILN 15 MM BTU/HR, SCC
CONFIDENTIAL 1994	NO.12 ROTARY KILN WITH CYCLONE, AND SCC	SOILS	70 MM BTU/HR, KILN 110 MMBTU/HR,SCC
CONFIDENTIAL 1996	MODEL 500 ROTARY KILN WITH FEED AND ASH SYSTEM, SCC, APC, FAN, STACK, AND PLUME SUPPRESSION SYSTEM MODULAR INCINERATOR	RCRA COMMERCIAL WASTE	6.5 MMBTU/HR, KILN 5 MMBTU/HR, SCC
CONFIDENTIAL 1996 EUROPE	NO. 9 ROTARY KILN WITH FEED AND ASH SYSTEMS. WITH ABB SUPPLIED WASTE HEAT RECOVERY BOILER, MULTI STAGE DRY SCRUBBER, PLC AND SCADA SYSTEM.	PHARMACEUTICAL WASTE	25 MMBTU/.HR KILN 15 MMBTU/HR SCC

Table 15 (Cont.). RAYMOND™ ROTARY KILN SYSTEMS

CUSTOMER	EQUIPMENT	WASTE	THERMAL (TOTAL)
ALLEN BRADLEY	ROTARY KILN	METAL SLUDGE	5 MM BTU/HR
AMOCO CHEMICAL	ROTARY KILN, SCC, APC	TPA RESIDUE	(2) - 60 MM BTU/HR
AMOCO CHEMICAL	ROTARY KILN, SCC, APC	CHEMICAL WASTE	1 MM BTU/HR
BASRAH PETROCHEM	ROTARY KILN, SCC, APC	PLASTIC BIO SLUDGE	5 MM BTU/HR
BETHLEHEM STEEL	ROTARY KILN	METAL SLUDGE	5 MM BTU/HR
CHEMICAL WASTE MGM'T	ROTARY KILN	HAZARDOUS WASTE	60 MM BTU/HR
CITY OF CHICAGO	ROTARY KILN	MSW	(3) - 80 MM BTU/HR
CITY OF CINCINNATI	ROTARY KILN	MSW	60 MM BTU/HR
CITY OF LOUISVILLE	ROTARY KILN, SCC, APC	MSW	30 MM BTU/HR
DOW CHEMICAL	ROTARY KILN	LL RAD. WASTE	40 MM BTU/HR
EASTMAN KODAK	ROTARY KILN	SEWAGE SLUDGE	50 MM BTU/HR
E. I. DUPONT	ROTARY KILN, SCC	CHEMICAL WASTE	5 MM BTU/HR
ELI LILLY	ROTARY KILN, SCC	PHARMACEUTICALS	60 MM BTU/HR
ENGLEHARDT	ROTARY KILN, SCC, APC	METAL SLUDGE	40 MM BTU/HR
FLUOR CORP.	ROTARY KILN	CHEMICAL WASTE	40 MM BTU/HR
HARSHAW CHEMICAL	ROTARY KILN, SCC, APC	CHEM & METAL SLUDGE	(2) - 30 MM BTU/HR
M & T CHEMICAL	ROTARY KILN, SCC, APC	METAL SLUDGE	10 MM BTU/HR
3 M COMPANY	ROTARY KILN, SCC, APC	CHEMICAL WASTE	(2) - 25 MM BTU/HR
MORTON FOODS	ROTARY KILN, SCC, APC	SLUDGES	5 MM BTU/HR
PP&G	ROTARY KILN, SCC, APC	CHEMICAL WASTE	15 MM BTU/HR
RADFORD ARSENAL	ROTARY KILN	MILITARY WASTE	15 MM BTU/HR
RADFORD ARSENAL	ROTARY KILN	MILITARY WASTE	5 MM BTU/HR
RICHARDSON-MERRELL	ROTARY KILN, SCC, APC	BIOLOGICAL WASTE	3 MM BTU/HR
ROLLINS ENVIRONMENTAL	ROTARY KILN	HAZARDOUS WASTE	(3) - 60 MM BTU/HR
SOUTH DADE COUNTY	ROTARY KILN, SCC, APC	MSW, MEDICAL	40 MM BTU/HR
SUNFLOWER ARSENAL	ROTARY KILN, SCC, APC	ROCKET PROPELLANT	10 MM BTU/HR

Table 15 (Cont.). RAYMOND™ ROTARY KILN SYSTEMS

CUSTOMER	EQUIPMENT	WASTE	THERMAL (TOTAL)
TRANS ALASKA CORP.	ENGINEERING ONLY	OIL & DRILLING SLUDGE	40 MM BTU/HR
TENNESSEE EASTMAN	ROTARY KILN, SCC, APC	CHEMICAL WASTE	40 MM BTU/HR
U.S. NAVY	ROTARY KILN, SCC, APC	TANK BOTTOMS, SOLVENTS	5 MM BTU/HR
WALLOVER OIL	ROTARY KILN, SCC, APC	DIATOMACEOUS EARTH	2 MM BTU/HR
WYANDOTTE CHEMICAL	ENGINEERING ONLY	CHEMICAL WASTE	2 MM BTU/HR

Table 16. SVEDALA ROTARY KILN SYSTEMS

	PROJECT/CUSTOMER	YEAR	WASTE TYPE	TYPE OF EQUIPMENT	HEAT RELEASE/ PRIMARY-SECONDARY	COMMENTS
1	WEST VIRGINIA PULP & PAPER	1965	CHEMICAL WASTES	ROTARY KILN 15 X 80	145 MMBTU/HR	EQUIPMENT SUPPLY
2	WEST VIRGINIA PULP AND PAPER	1966	CHEMICAL WASTES	ROTARY KILN 15 X 80	145 MMBTU/HR	EQUIPMENT SUPPLY
3	MONSANTO/ENVIRO-CHEM	1973	MUNICIPAL REFUSE	ROTARY KILN 20 x 100	250 MBTU/HR	EQUIPMENT SUPPLY
4	GENERAL ELECTRIC	1979	CHEMICAL WASTES	ROTARY KILN 12.5 X 35	45 MBTU/HR	DRUM WASTE FED INTO SYSTEM
5	ROY F. WESTON	1986	PCB SOILS	ROTARY KILN 7.5 X 25, SCC	35 MBTU/HR	TRANSPORTABLE SYSTEM/THREE SITES
6	INTERNATIONAL TECHNOLOGY	1986	CONTAMINATED SOILS	ROTARY KILN 7.5 X 45	50 MBTU/HR	TRANSPORTABLE SYSTEM/THREE SITES
7	DUPONT CORPORATION	1986	CONTAMINATED SOILS	ROTARY KILN 7.7 X 45	50 MBTU/HR	ON-SITE CLEANUP/TRANSPOR-TABLE SYSTEM
8	DEPT. OF ARMY	1987	CHEMICAL WASTES	CONFIDENTIAL	CONFIDENTIAL	CONFIDENTIAL
9	WASTE TECH SERVICES	1988	CHEMICAL WASTES	ROTARY KILN 10.5 X 30, SCC	50 MBTU/HR	FIXED PROCESS SITE
10	DEPT. OF ENERGY	1988	URANIUM RECOVERY	CONFIDENTIAL	CONFIDENTIAL	CONFIDENTIAL
11	McGILL ENVIRONMENTAL	1988	CHEMICAL WASTE	ROTARY KILN 9.5 X 30	50 MBTU/HR	TURNKEY TRANSPORTABLE SYSTEM
12	ENVIRITE FIELD SERVICES	1988	CONTAMINATED SOILS	ROTARY KILN 7.5 X 45	50 MBTU/HR	TRANSPORTABLE SYSTEM
13	McGILL ENVIRONMENTAL	1988	HAZARDOUS WASTE	ROTARY KILN 7.5 X 45	50 MBTU/HR	TRANSPORTABLE SYSTEM
14	GLAXO CO.	1989	BIOMEDICAL WASTE	FIXED HEARTH HR 75, SCC	8 MBTU/HR	BIOHAZARDOUS/RADIOACTIVE RESEARCH
15	DUPONT CORPORATION	1989	INDUSTRIAL WASTE	ROTARY KILN 12 X 50, SCC	60 MBTU/HR	TURNKEY SYSTEM/WASTE HEAT RECOVERY

Table 16 (Cont.). SVEDALA ROTARY KILN SYSTEMS

	PROJECT/CUSTOMER	YEAR	WASTE TYPE	TYPE OF EQUIPMENT	HEAT RELEASE/ PRIMARY-SECONDARY	COMMENTS
16	USPCI/STEARNS	1990	CONTAMINATED SOILS	ROTARY KILN 10 X 85	40 MBTU/HR	REGIONAL COMMERCIAL FACILITY
17	USPCI/STEARNS	1990	CHEMICAL WASTES	ROTARY KILN 16 X 50	100 MBTU/HR	REGIONAL COMMERCIAL FACILITY
18	IT McGILL	1990	CONTAMINATED SOIL	ROTARY KILN 13.5 X 75	145 MBTU/HR	TRANSPORTABLE SYSTEM
19	WASTE TECH SERVICES	1991	CHEMICAL WASTES	ROTARY KILN 11 X 40, SCC	75 MBTU/HR	PETRO-CHEMICAL FACILITY
20	MERCK & CO.	1991	BIOMEDICAL WASTES	ROTARY KILN 8 X 20, SCC	10 MBTU/HR	COMPLETE SYSTEM/MULTIPLE FEED SYSTEM
21	ORTHO PHARMACEUTICAL	1992	BIOMEDICAL WASTES	ROTARY KILN 8 X 20, SCC	15 MBTU/HR	COMPLETE SYSTEM/MULTIPLE FEED SYSTEM
22	MERCK & CO.	1992	BIOMEDICAL WASTES	ROTARY KILN 10 X 35, SCC	30 MBTU/HR	COMPLETE SYSTEM/MULTIPLE FEED SYSTEM
23	IT-OHM	1992	HAZARDOUS WASTE	ROTARY KILN 13.5 X 75, SCC	145 MBTU/HR	EQUIPMENT SUPPLY
24	E. YOUNG CHEMICAL	1992	INDUSTRIAL WASTES	ROTARY KILN 12 X 50, SCC	60 MBTU/HR	PROCESS DESIGN AND EQUIPMENT SUPPLY
25	MT. SINAI MEDICAL CENTER	1992	BIOMEDICAL WASTES	ROTARY KILN 8 X 20, SCC	10 MBTU/HR	TURNKEY SYSTEM
26	CHI MEI CORPORATION	1993	INDUSTRIAL WASTES	ROTARY KILN 12.5 X 55, SCC	70 MBTU/HR	COMPLETE SYSTEM
27	MITSUI/HIRAKAWA GUIDOM	1994	INDUSTRIAL WASTES	ROTARY KILN 5' X 15'	2.7 MBTU/HR	TEST KILN FOR JAPAN
28.	ANDERSON 2000	1995	HAZARDOUS WASTES	ROTARY KILN 11.5' X 30'	25 MMBTU/HR	EQUIPMENT SUPPLY
29.	DANISH WASTE MANAGEMENT	1995	HAZARDOUS WASTES	ROTARY KILN 11' X 40'	55 MBTU/HR	COMPLETE SYSTEM

FULL-SCALE OPERATION

This section covers plant description and equipment list for a full-scale plant based on the Cement-Lock Technology.

Plant Description

A full-scale plant is designed to treat from 100,000 to 500,000 cubic yards of sediments per year, and convert the sediments to a blended cement product on a continuous basis. The plant consists of one to five operating trains, and is divided into the following four major processing sections.

Section 100	Feed Preparation
Section 200	Sediments Treatment and Ecomelt Generation
Section 300	Flue Gas Clean-Up
Section 400	Cement Production

A simplified overall flow scheme with key components of each section is shown in Figure 7.

Section 100: Feed Preparation

In this section, sediments are received and mixed with solid modifiers as a feed material for Section 200.

Sediments are received at the plant by barges. It is then dumped into a storage pit from where it is pumped into an Ecomelt generator. Solid Modifiers are pneumatically transferred from the supply trucks to a Solid Modifiers Silo. The silo is equipped with drag chain conveyors, each of which feeds pneumatically to a Solid Modifiers Hopper. The solids are then fed to the Ecomelt generator by rotary air-lock and screw feeder.

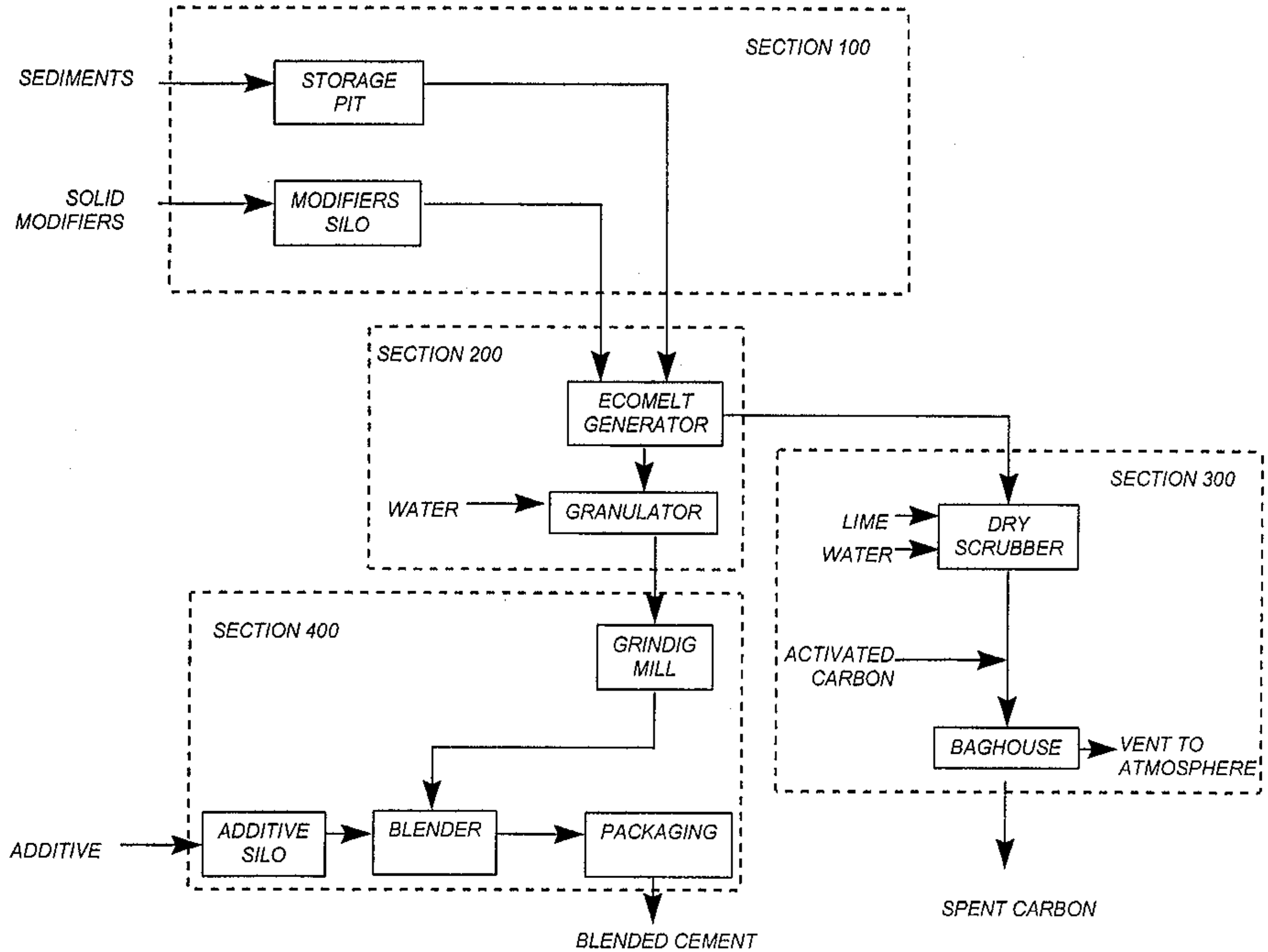


Figure 7. SCHEMATIC FLOW DIAGRAM FOR A SEDIMENTS TREATMENT PLANT BASED ON CEMENT-LOCK TECHNOLOGY

Section 200: Sediments Treatment and Ecomelt Generation

The sediments-modifier mixture is melted in the Ecomelt Generator at high temperature in the presence of oxygen. Organic contaminants originally present in the sediments are completely destroyed and converted to carbon dioxide and water. Chlorine present in some of the organic compounds (such as chlorinated dioxins, furans, and PCBs) is reduced to hydrogen chloride which is either sequestered in the melt or readily scrubbed from the flue gas in the Flue Gas Clean-Up Section. Heavy metals present in the sediments are immobilized in the melt.

The melt is quenched and granulated in a Granulator by direct contact with water spray. An adequate amount of water spray is provided in the Granulator to ensure a rapid quench of the melt and prevent crystallization of the melt. The melt is broken into small Ecomelt granules by the impingement of water jets. Ecomelt granules are de-watered through an inclined conveyor and discharged to an Ecomelt Hopper. Water discharged from the Granulator is cooled in a Quench Water Cooler and recycled to the spray section of the Granulator.

Section 300: Flue Gas Clean-Up

Hot flue gas is cooled to temperatures such that inexpensive standard air pollution equipment can be used for gas clean up. The cooling may be achieved by direct contact with water in an evaporative cooler or indirectly through a waste heat boiler. In a direct-contact evaporative cooler design, the flue gas leaving the Ecomelt Generator is cooled by contact with lime-water slurry in a Dry Scrubber. Gaseous pollutants such as chlorides are absorbed by lime slurry and converted to lime salts. The lime salts are removed from the flue gas in a Baghouse and recycled to the Ecomelt Generator. Other gaseous pollutants are captured in a packed-bed Activated Carbon Column. The effluent gas is then vented to the atmosphere through an Induced Draft Fan.

Section 400: Cement Production

Ecomelt granules are pulverized to about 20 microns in an Ecomelt Grinding Mill. The mill is equipped with an air classifier where oversized Ecomelt particles are returned to the mill, and the pulverized Ecomelt particles are collected by a Cyclone. The pulverized Ecomelt is then blended with a predetermined quantity of solid additive in a Cement Blender. The blended cement product is packed in 80-lb bags at a Packing Station.

Equipment List

The major equipment items for each processing section are listed in Tables 17 through 20.

Table 17. EQUIPMENT LIST FOR A SEDIMENTS TREATMENT PLANT BASED ON CEMENT-LOCK TECHNOLOGY (Feed Preparation Section)

Solid Modifiers Conveyor

Modifiers Unloading Conveyor

Sediments Feed Pump

Solid Modifiers Feeder

Solid Modifiers Silo

Solid Modifiers Hopper

Solid Modifiers Surge Hopper

Table 18. EQUIPMENT LIST FOR A SEDIMENTS TREATMENT PLANT BASED ON CEMENT-LOCK TECHNOLOGY (Sediments Treatment and Ecomelt Generation Section)

Ecomelt Conveyors

Ecomelt Generator

Ecomelt Granulator

Quench Water Cooler

Quench Water Pump

Pulverized Ecomelt Hopper

Table 19. EQUIPMENT LIST FOR A SEDIMENTS TREATMENT PLANT BASED ON CEMENT-LOCK TECHNOLOGY (Flue Gas Clean-Up Section)

Induced Draft Fan

Bag House

Spent Carbon Conveyor

Air Compressor

Lime Feeder

Lime Slurry pump

Dry Scrubber

Lime Slurry Tank

Lime Hopper

Activated Carbon Column

Vent

Table 20. EQUIPMENT LIST FOR A SEDIMENTS TREATMENT PLANT BASED ON CEMENT-LOCK TECHNOLOGY (Cement Production Section)

Additive Blower
Blended Cement Blower
Cement Blender
Cement Conveyor
Additive Conveyor
Pulverized Ecomelt Feeder
Additive Feeder
Cement Feeder
Ecomelt Grinding Mill System
Cement Packer
Pulverized Ecomelt Hopper
Additive Silo
Cement Silo
Additive Surge Hopper

COMMERCIALIZATION OF CEMENT-LOCK TECHNOLOGY

Because of the importance of the Cement-Lock Technology, IGT's subsidiary, ENDESCO Services, Inc. is assembling the following, well-experienced team to accomplish the ambitious goals of all commercial projects in an expeditious and cost-effective manner. The team includes the following:

- Cement-Lock Group, L.L.C. – the licenser of the Cement-Lock Technology
- Institute of Gas Technology (IGT) – the research arm of the Cement-Lock Group, L.L.C., and developer of the technology
- an A&E (architecture and engineering) firm that will be selected from the list of Roy F. Weston, Metcalf and Eddy, Bechtel, Dames & Moore, and Foster Wheeler Environmental
- Equipment manufacturer that will be selected from Svedala, ABB Combustion Engineering, Ausmelt Technology Corporation, or other
- a plant construction company
- a cement manufacturer or ready-mix company to sell the product in the marketplace
- Construction Technology Laboratories, Inc. – the research arm of the Portland Cement Association.

Technology transfer will be provided by Cement-Lock Group, L.L.C. IGT will provide overall technical support during the plant design stages as well as the initial plant operation. Construction Technology Laboratories will provide support for cement testing and certification. ENDESCO will manage planning and execution of the construction and operation of the entire facility and will also act as the primary contact for the vendor.

ENDESCO Services, Inc., a wholly owned subsidiary of the Institute of Gas Technology, is located in Des Plaines, Illinois. The corporate objective of ENDESCO is to bring technologies developed by IGT as well as third-parties into the marketplace in profitable commercial ventures. Currently, ENDESCO is actively and aggressively marketing such technologies as Cement-Lock, ACIMET (two-stage anaerobic digestion process for sewage sludge), among others.

ENDESCO and IGT have been actively pursuing the commercialization of IGT technologies for many years. They have demonstrated an exceptional commercialization track record. Depending upon the characteristics of the technology and the appropriate marketplace, IGT will commercialize technology through new venture formation such as ENDESCO, partnerships, and technology transfer/license agreements.

Two recent examples of venture formation are:

- In 1987, IGT formed a subsidiary, M-C Power Corporation, for the purpose of manufacturing molten carbonate fuel cells for the electric power generation market based on IGT's fuel cell technology. In exchange for a license to use IGT's technology, IGT received a 51 percent ownership in M-C Power. The remaining 49 percent is equally owned by Bechtel Corporation and Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI).

  1. M-C Power's role is to manufacture the fuel cells,
  2. Bechtel Corporation will engineer the systems, and
  3. Stewart and Stevenson Corporation will fabricate the power plants.

  M-C Power is now in the demonstration phase of the full scale technology. Two demonstration programs have been completed in which 250 kW capacity complete systems were tested at utility sites. It is expected that commercial sales will begin in 2000. M-C Power now employees 75 people with a budget of $20 to $25 million per year.

- In 1991, IGT formed a joint venture, Shanghai Zhihai Gasification Technology Development Corp., Ltd., with Shanghai Coke and Chemical Company of the Peoples Republic of China, to design and construct coal gasification plants in China based on IGT's U-GAS technology. Eight coal gasifiers have recently been designed and constructed, and six gasifiers are now in various stages of operation.

IGT has also commercialized numerous technologies through license/partnership agreements with commercial firms (Table 21).

Table 21. COMMERCIALIZED IGT TECHNOLOGIES

IGT Technology	Licensee
• Oxygen Enriched-Air Staging (Glass Industry)	- Combustion Tec, Inc., Apopka, FL - Air Products and Chemicals, Inc., Allentown, PA
• High Luminosity Burner	- Combustion Tec., Inc. , Apopka, FL
• U-GAS® for coal gasification	- Enviropower, Inc., Tampere, Finland - Shanghai Zhihai Gasification Technology Development Corp., Ltd., Shanghai, Peoples Republic of China
• RENUGAS® for Biomass gasification	- The Pacific International Center for High Technology Research, Honolulu, Hawaii - Enviropower, Inc., Tampere, Finland
• Molten Carbonate Fuel Cells	- M-C Power Corporation, Burr Ridge, IL - Energieonderzoek Centrum Nederland Petten, The Netherlands
• Microbial Desulfurization	- Energy BioSystems Corporation, The Woodlands, TX
• ACIMET®	- DuPage Group, Woodridge, IL - Convergent Biomass Technologies, Inc., Round Lake, IL
• Methane de-NOX®	- Takuma Company Ltd., Osaka, Japan - Detroit Stocker Company, Monroe, MI
• Pre-mixed Cyclonic Burner	- Takuma Company Ltd., Osaka, Japan - Burnham Corporation, Lancaster, PA
• Nozzle-Mix Cyclonic Burner	- Donlee Technologies Inc., York, PA
• Oscillating Combustion	- American Air Liquide, Countryside, IL - L'Air Liquide, S.A., Paris, France
• Surface Combustor/Fluid Heater	- Takuma Company Ltd., Osaka, Japan
• High Temperature Industrial Furnace Probe	- Combustion Tec, Inc. , Apopka, FL
• Hot-Tap Sectionalizing Valve	- T.D. Williamson, Inc.

CONCLUSIONS AND RECOMMENDATIONS

The dredged river sediments were evaluated as a candidate for producing Ecomelt (a cementitious material) by melting with appropriate modifiers to partially replace portland cement for construction purposes. The Ecomelt was then mixed with an appropriate additive to produce blended cement, which can be sold in the marketplace.

Conclusions

The following conclusions are based on the results of the bench-scale experimental study conducted in this program:

- The organic contaminants in the blended cement (end product of the Cement-Lock process), such as oil and grease, PAHs, and PCBs, were below the detection limit of the analytical procedures used. This indicates that these species, which are present in the untreated sediments, are completely destroyed in the process.
- The results of the EPA TCLP procedure conducted on the blended cement product showed that the leachability of the priority metals from the blended cement was significantly below the regulatory limit for each of the metals. This demonstrates that the metals present in the untreated sediments are immobilized in the final product.
- Based on its physical and chemical characteristics, about 83% sediments and only 17% inexpensive modifiers were used to generate Ecomelt of sufficient reactivity. It may be possible to further reduce the amount of modifiers required at relatively low temperatures by additional testing with the sediments.
- The blended cement contains 40 percent Ecomelt (the maximum replacement allowed by the ASTM C 595 specification) and generated 3, 7, and 28-day compressive strengths which are greater than those required for general purpose cement (per ASTM C 595, C 1157, and C 150 specifications). It is significant to note that the blended cement product did not require the use of any activators (performance enhancing additives).
- The quantities of trace metals present in the blended cement are within acceptable cement industry limits (that is, they are similar to those present in portland cement).

The Cement-Lock Technology is now ready for a pilot-scale demonstration with contaminated river sediments. Previous studies conducted at IGT with dredged estuarine sediments at bench-scale and pilot-scale levels yielded similar results in terms of organic destruction, metals immobilization, and cement quality. Results from a pilot-scale operation with river sediments are also expected to be similar to those achieved in the bench-scale testing.

The Cement-Lock process economics are also very favorable because of the dual revenue streams associated with the process: processing (tipping) fees received for the contaminated river sediments and revenues received from the sale of the cement product.

Recommendations for Further Work

This study has clearly indicated that contaminated river sediments can be treated and transformed into salable blended cement using the Cement-Lock Technology. The blended cement product generated 3, 7, and 28-day compressive strengths greater than those required for general purpose cement (per ASTM C 595, C 1157, and C 150 specifications). However, more characterization tests are required on the cement product before it can be adopted for general construction purposes. These tests include drying shrinkage, setting times, heat of hydration, air content, autoclave expansion and contraction, and sulfate resistance.

Based on the favorable experimental results achieved here as well as those with harbor sediments, it is recommended that the Cement-Lock process for contaminated river sediments be advanced to pilot-scale demonstration.

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